ELECTRIC COMPRESSOR

BACKGROUND OF THE INVENTION

The present invention relates to an electric compressor for use in a vehicle air conditioner.

Unexamined Japanese Utility Model Publication No. 62-12471 discloses a conventional electric compressor. An inverter is mounted on the surface of a compressor housing for driving an electric motor. Refrigerant in relatively low temperature flows in the electric compressor, and heat is exchanged through the compressor housing between the refrigerant and switching devices of the inverter. Accordingly, the inverter is cooled without additional components such as a radiator and a blower.

An unwanted feature is that, when an electric compressor employs the above structure disclosed in Unexamined Japanese Utility Model Publication No. 62-12471, generally, a plurality of the switching devices is directly fastened to the outer surface of the compressor housing through bolts, respectively. Each of the switching devices needs the bolt so that the number of components and assembling processes increase. A tapped hole for screwing the bolt needs to be plurally formed in the compressor housing. Thus, manufacturing costs increase

for the electric compressor.

Additionally, when an electric compressor employs the structure disclosed in Unexamined Japanese Utility Model Publication No. 62-12471, generally, after the switching devices has been mounted on the compressor housing, the switching devices are wired and the other electrical components are mounted on the compressor housing. However, assembling the components of the inverter to the compressor housing requires careful attention so that it is incompatible with an assembling process for a mechanism of the electric compressor because the mechanism allows less careful attention in the assembling process than the components of the inverter. For example, the above two assembling processes do not agree on the configuration of assembly line and the method of moving the assembly line.

Accordingly, when the inverter needs to be accurately assembled on the compressor housing, the assembly line for the inverter needs to be separated from the assembly line for the mechanism of the compressor. In this state, the compressor housing or a relatively large component must be moved between the assembly lines so that it spends time and energy. As a result, manufacturing costs increase for the electric compressor.

Furthermore, when the inverter is directly assembled on the compressor

housing, checking the inverter becomes difficult. Namely, when an operator checks operation of the inverter, the compressor housing should also be handled together so that it also spends time and energy. Thus, manufacturing costs increase for the electric compressor. Therefore, there is a need for an electric compressor that effectively radiates heat of the switching device with a low-cost structure.

SUMMARY OF THE INVENTION

In accordance with the present invention, an electric compressor has a compressor housing, a compression mechanism, an electric motor, a circuit cover and a motor drive circuit. The compression mechanism is arranged in the compressor housing for compressing fluid. The electric motor is arranged in the compressor housing for driving the compression mechanism. The circuit cover is connected to an outer surface of the compressor housing. The circuit cover and the compressor housing define an accommodating space. The motor drive circuit is arranged in the accommodating space for driving the electric motor and includes a substrate and a switching device that is mounted on the substrate on the far side relative to the circuit cover. The switching device is pressed against the compressor housing as the motor drive circuit is fastened between the compressor housing and the circuit cover in the accommodating space due to connection of the circuit cover to the compressor housing.

Other aspects and advantages of the invention will become apparent from the following description, taken in conjunction with the accompanying drawings, illustrating by way of example the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The features of the present invention that are believed to be novel are set forth with particularity in the appended claims. The invention together with objects and advantages thereof, may best be understood by reference to the following description of the presently preferred embodiments together with the accompanying drawings in which:

FIG. 1 is a longitudinal cross-sectional view of a motor compressor according to a first preferred embodiment of the present invention;

FIG. 2 is a side view of the motor compressor according to the first preferred embodiment of the present invention;

FIG. 3 is an enlarged cross-sectional end view that is taken along the line I-I in FIG. 2 in a state when a rotary shaft and an electric motor are detached;

FIG. 4A is a partially enlarged cross-sectional end view of a motor compressor according to a second preferred embodiment of the present invention;

FIG. 4B is a partially exploded cross-sectional end view of the motor compressor according to the second preferred embodiment of the present invention;

FIG. 5 is a partially enlarged cross-sectional end view of a motor compressor according to a third preferred embodiment of the present invention; and

FIG. 6 is a partially enlarged cross-sectional end view of a motor compressor according to a fourth preferred embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

First through fourth preferred embodiments applies the present invention to a motor compressor of a refrigerant circuit in a vehicle air conditioner. In the second through fourth preferred embodiments, the different components and features to those in the first preferred embodiment are described, and the same reference numerals denote the substantially identical components to those in the

first preferred embodiment.

The first preferred embodiment of the present invention will now be described in reference to FIGs. 1 through 3.

Now referring to FIG. 1, a diagram illustrates a longitudinal cross-sectional view of a motor compressor or an electric compressor 10 according to the first preferred embodiment of the present invention. A compressor housing 11 forms an outer shell of the motor compressor 10. The compressor housing 11 includes a first housing element 21 and a second housing element 22. The first housing element 21 has a substantially cylindrical circumferential wall 23 and an end wall that is formed on the left end of the circumferential wall 23. That is, the first housing element 21 forms a cylinder with a bottom wall on the left side of the drawing. The first housing element 21 is die-cast in an aluminum alloy. The second housing element 22 forms a cylinder with an end wall on the right side of the drawing and is die-cast in an aluminum alloy. As the first and second housing elements 21, 22 are fixedly connected with each other, a closed space 24 is defined in the compressor housing 11.

A rotary shaft 27 is rotatably supported by the first housing element 21 in the closed space 24 and has a central axis of rotation L that is identical to the central axis L of the motor compressor 10. The circumferential wall 23 of the first

housing element 21 surrounds the central axis L of the motor compressor 10.

An electric motor 12 and a compression mechanism 14 are accommodated in the closed space 24 of the compressor housing 11. The electric motor 12 includes a stator 12a and a rotor 12b. The stator 12a is fixedly connected to an inner surface of the circumferential wall 23 of the first housing element 21. The rotor 12b is provided on the rotary shaft 27 and is arranged inside the stator 12a. The electric motor 12 rotates the rotary shaft by electric power that is supplied to the stator 12a.

The compression mechanism 14 is a scroll type and includes a fixed scroll member 14a and a movable scroll member 14b. As the movable scroll member 14b orbits relative to the fixed scroll member 14a in accordance with the rotation of the rotary shaft 27, the compression mechanism 14 compresses refrigerant gas or fluid. An outlet 32 is formed in the second housing element 22 for discharging the compressed refrigerant gas to an external refrigerant circuit, which is not shown in the drawing.

As the electric motor 12 drives the compression mechanism 14, the refrigerant gas in relatively low temperature and in relatively low pressure is introduced from the external refrigerant circuit into the compression mechanism 14 through the electric motor 12. The introduced refrigerant gas is compressed to

have relatively high temperature and relatively high pressure by the compression mechanism 14. Then, the refrigerant gas is discharged to the external refrigerant circuit through the outlet 32. Incidentally, the refrigerant gas from the external refrigerant circuit cools the electric motor 12 as it passes by the electric motor 12.

Now referring to FIG. 2, a diagram illustrates a side view of the motor compressor 10 according to the first preferred embodiment of the present invention. An inlet 31 is formed in the first housing element 21. The refrigerant gas is introduced from the external refrigerant circuit into the compressor housing 11 through the inlet 31.

Now referring to FIG. 3, a diagram illustrates a partially enlarged cross-sectional view that is taken along the line I-I in FIG. 2. The first housing element 21 partially includes an accommodating portion 36. The accommodating portion 36 is provided on a portion of the outer surface of the circumferential wall 23 and defines an accommodating space 35 inside. The accommodating portion 36 includes a frame-shaped side wall 37 and a cover member or a circuit cover 38. The side wall 37 is integrally formed with the circumferential wall 23 and extends from the outer surface of the circumferential wall 23. The cover member 38 for covering a circuit is fixedly connected to the distal end surface of the side wall 37. The cover member 38 forms a thin plate and is made of metal such as an aluminum alloy. The cover member 38 is fixed to the side wall 37 by fastening

bolts 39 at the four corners.

The outer surface of the circumferential wall 23 defines a bottom surface 35a of the accommodating space 35. Namely, the bottom surface 35a of the accommodating space 35 is defined by the first housing element 21. The cover member 38 defines a substantially planar top surface 35b of the accommodating space 35.

A motor drive circuit 41 is accommodated in the accommodating space 35 in the accommodating portion 36 for driving the electric motor 12. The motor drive circuit 41 includes an inverter and supplies the stator 12a of the electric motor 12 with electric power based on a command from an air conditioner ECU, which is not shown in the drawing. Incidentally, the refrigerant gas cools the motor drive circuit 41 as it is introduced from the external refrigerant circuit to the compression mechanism 14 through the electric motor 25. Namely, the refrigerant gas flows by the opposite side of a portion of the compressor housing 11 where the accommodating space 35 is positioned.

The motor drive circuit 41 includes a planar substrate 43 and a plurality of electrical components 44. The electrical components 44 are respectively mounted on surfaces 43a, 43b of the substrate 43. Namely, the electrical components 44 are respectively mounted on the substrate 43 on the near and far sides relative to

the central axis L. Incidentally, the electrical components 44 include electrical components 44A through 44E and other electrical components, which are not shown in the drawing.

The electrical components 44 include known components for constituting the inverter. That is, the electrical components 44 include a switching device 44A, an electrolytic condenser 44B, a transformer 44C, a driver 44D, a fixed resistance 44E and the like. The driver 44D is an integrated circuit chip or an IC chip for intermittently controlling the switching device 44A based on the command from the air conditioner ECU.

The switching device 44A is mounted on the surface 43a of the substrate 43 that is, on the substrate 43 on the near side relative to the central axis L. Some of the electrical components 44 are shorter from the substrate 43 than the switching device 44A if they are mounted on the same surface. Only the above shorter electrical components 44 are mounted on the surface 43b of the substrate 43, that is, on the substrate 43 on the far side relative to the central axis L. Namely, the above shorter electrical components 44 are mounted on the substrate 43 on the near side relative to the cover member 38. The above shorter electrical components 44 include the driver 44D and the fixed resistance 44E.

Some of the electrical components 44 are taller from the substrate 43, or

from the surface 43a, than the switching device 44A. The taller electrical components 44 and the switching device 44A are mounted on the surface 43a of the substrate 43, that is, on the substrate 43 on the near side relative to the central axis L. Namely, the taller electrical components 44 are mounted on the substrate 43 on the far side relative to the cover member 38. The taller electrical components 44 include the electrolytic condenser 44B and the transformer 44C. Accordingly, among the electrical components 44 on the surface 43a of the substrate 43, the switching device 44A corresponds to a short electrical component, and the electrolytic condenser 44B and the transformer 44C correspond to tall electrical components.

The short electrical components such as the switching device 44A are arranged at the middle portion of the surface 43a of the substrate 43. The tall electrical components such as the electrolytic condenser 44B and the transformer 44C are arranged on both sides of the middle portion of the surface 43a. Namely, the short electrical components are arranged relatively closer to the central axis L, while the tall electrical components are arranged relatively farther from the central axis L. As arranged above, the motor drive circuit 41 is installed to the compressor housing 11 in such a manner that the electrical components 44 on the surface 43a of the substrate 43 line a substantially cylindrical surface of the circumferential wall 23.

In the motor drive circuit 41 in the accommodating space 35, the electrical components 44 are arranged on the surface 43a of the substrate 43 along the cylindrical shape of the circumferential wall 23. Therefore, the motor drive circuit 41 is arranged to approach the central axis L of the motor compressor 10 because the electrical components 44 line the cylindrical surface of the circumferential wall 23. Accordingly, the protrusion of the accommodating portion 36 from the compressor housing 11 in the direction perpendicular to the central axis L is reduced so that the motor compressor 10 is reduced in size.

The bottom surface 35a of the accommodating space 35 includes a planar middle region 35a-1 that corresponds with the switching devices 44A. The middle region 35a-1 approaches the cover member 38 and is parallel with the top surface 35b. In the bottom surface 35a of the accommodating space 35, a region on both sides of the middle region 35a-1 forms a recess 35a-2 for accommodating the tall electrical components, such as the electrolytic condenser 44B and the transformer 44C.

Since the motor drive circuit 41 near the switching devices 44A is fastened between the first housing element 21 and the cover member 38 by fixing the cover member 38 to the first housing element 21, the motor drive circuit 41 is fixed in the accommodating space 35. Due to the fastening between the first housing element 21 and the cover member 38, that is, the bottom surface 35a of

the accommodating space 35 and the top surface 35b, the switching devices 44A of the circuit 41 is pressed against the bottom surface 35a of the accommodating space 35 or the middle region 35a-1 at a heat radiating surface 44A-1.

Substrate support members 47 made of resin plate are fixedly connected to the surface 43b of the substrate 43 on the far side relative to the central axis L and are arranged on the substrate 43 on the far side relative to the switching devices 44A. The substrate support members 47 are taller from the surface 43b than any of the electrical components 44 mounted on the surface 43b. Accordingly, a load exerting on the switching devices 44A as the switching devices 44A are pressed against the bottom surface 35a of the accommodating space 35. The cover member 38 receives the load through the substrate 43 and the substrate support members 47. Accordingly, the substrate 43 substantially does not deform due to the direct support of the substrate support members 47.

A rubber sheet or a first elastic member 45 is interposed between the switching devices 44A and the bottom surface 35a, or the middle region 35a-1, of the accommodating space 35 and has relatively high insulating performance, relatively high elasticity and relatively high heat conductivity. Therefore, the switching devices 44A are pressed against the bottom surface 35a of the accommodating space 35 through the sheet 45 so as to be adjacent to the bottom surface 35a. A rubber sheet or a second elastic member 46 is interposed between

the substrate support members 47 and the top surface 35b of the accommodating space 35 and has relatively high insulating performance and relatively high elasticity. Therefore, the substrate support members 47 are pressed against the top surface 35b of the accommodating space 35 through the sheet 46.

According to the first preferred embodiment, the following advantageous effects are obtained.

(1) The switching devices 44A of the motor drive circuit 41 are each pressed against the bottom surface 35a, or the first housing element 21, in the accommodating space 35 so as to be adjacent to the first housing element 21. As a result, heat is effectively exchanged between the switching devices 44A and first housing element 21 that is relatively low in temperature due to flow of suction refrigerant in relatively low temperature. Accordingly, heat is efficiently radiated from the switching devices 44A so that the motor drive circuit 41 operates in stable.

The force pressing the switching devices 44A against the first housing element 21 is generated by fastening the motor drive circuit 41 between the first housing element 21 and the cover member 38 in the accommodating space 35 as the cover member 38 is fixedly connected to the first housing element 21. Accordingly, in a state when the structure disclosed in Unexamined Japanese

Utility Model Publication No. 62-12471 is employed, switching devices do not need to be directly bolted to a compressor housing. Additionally, after the motor drive circuit 41 has been assembled, the circuit 41 may be mounted on the compressor housing 11. Accordingly, in a state when the structure disclosed in Unexamined Japanese Utility Model Publication No. 62-12471 is employed, various troubles due to assembling an inverter on a compressor housing is avoided. Thus, when the structure is provided for improving heat radiation performance of the switching devices 44A, the low-cost motor compressor 10 is provided.

(2) The sheet 45 having relatively high elasticity, relatively high insulating performance and relatively high heat conductivity is interposed between the first housing element 21 and the switching devices 44A of the motor drive circuit 41. The sheet 46 having relatively high elasticity is interposed between the cover member 38 and the motor drive circuit 41.Accordingly, for example, even if the height of the switching devices 44A on the substrate 43 are inconsistent due to dimensional tolerance, each of the sheets 45, 46 deform to cancel the absolute inconsistent height and the relatively inconsistent height among the switching devices 44A. Thus, the switching devices 44A are firmly arranged adjacent to the first housing element 21. As a result, heat radiation performance of the switching devices 44A improves and the motor drive circuit 41 is arranged in the accommodating space 35 in stable.

Furthermore, in the first preferred embodiment, the two sheets 45, 46 cooperatively cancel the inconsistent height among the switching devices 44A on the substrate 43. Accordingly, maximum elastic deformation required for the sheets 45, 46 becomes relatively small so that the sheets 45, 46 may be relatively thin. Particularly, since the sheet 45 between the first housing element 21 and the switching devices 44A is thin, heat conductivity between the first housing element 21 and the switching devices 44A improves. Thus, heat radiation performance of the switching devices 44A further improves. Additionally, since the motor drive circuit 41 is sandwiched by the elastic sheets 45, 46, it performs high resistance against vibration.

(3) The substrate support member 47 is interposed between the cover member 38 and the motor drive circuit 41 and supports the substrate 43 around the switching devices 44A. Accordingly, the switching devices 44A are pressed against the first housing element 21 so that the substrate 43 tends to deform toward the switching devices 44A. However, the above support prevents the deformation of the substrate 43. Thus, damage of the substrate 43 and peeling at the soldering portion of the switching device 44A due to the deformation of the substrate 43 are prevented.

The second preferred embodiment of the present invention will now be

described in reference to FIGs. 4A, 4B.

Now referring to FIG. 4A, a diagram illustrates a partially enlarged cross-sectional end view of the motor compressor 10 according to the second preferred embodiment of the present invention. Instead of the sheet 46, a resin spacer 51 is arranged at the same position as the sheet 46 in the second preferred embodiment.

Now referring to FIG. 4B, a diagram illustrates a partially exploded cross-sectional end view of the motor compressor 10 according to the second preferred embodiment of the present invention. The sheet 45 elastically deforms by adjusting a thickness X1 of the spacer 51 so that force appropriately presses the switching devices 44A against the bottom surface 35a of the first housing element 21. Namely, as described in the advantageous effect of the paragraph (2) in the first preferred embodiment, when the single elastic sheet 45 is used for reliably canceling absolute and relative inconsistent height among the switching devices 44A, the sheet 45 becomes large in thickness so that heat radiation performance deteriorates in the switching devices 44A.

Therefore, in the second preferred embodiment, a thickness X2 around the switching devices 44A of the motor drive circuit 41 is measured. The thickness X2 is a distance between the distal end of the substrate support member 47 and

the distal end of the highest switching device 44A on the substrate 43. That is, the thickness X2 is a distance between the upper surfaces of the substrate support members 47 in the drawing and the heat radiating surfaces 44A-1. A differential is calculated between the thickness X2 and an appropriate thickness X3. Then, the thickness X1 of the spacer 51 is selected in accordance with the above calculated differential from the prepared spacers 51 having various thickness, and the selected spacer 51 is interposed between the motor drive circuit 41 and the cover member 38, that is, between the substrate support members 47 and the top surface 35b of the accommodating space 35.

Incidentally, the selected thickness X1 of the spacer 51 does not need to fulfill the expression $X3 - X2 = X1$ but may have tolerance as far as the selected thickness X1 is close to the value calculated from the above expression. In other words, even if the selected spacer 51 has the thickness X1 that does not fulfill the above expression, the tolerance is canceled by elastic deformation of the sheet 45.

The third preferred embodiment of the present invention will now be described in reference to FIG. 5.

Now referring to FIG. 5, a diagram illustrates a partially enlarged cross-sectional end view of the motor compressor 10 according to the third

preferred embodiment of the present invention. The sheet 46 in the first preferred embodiment is omitted in the third preferred embodiment. The thickness X2 of FIG. 4B is adjusted to the appropriate thickness X3 of FIG. 4A by adjusting the thickness of the substrate support members 47.

The thickness of the substrate support members 47 may be adjusted by selecting the appropriate thickness of the substrate support members 47 from the prepared substrate support members 47 having various thickness, as well as the spacer 51 of the second preferred embodiment. Otherwise, the substrate support members 47 are directly formed by padding resin on the substrate 43, and the motor drive circuit 41 is pressed toward the cover member 38 during times when the resin is still soft, that is, when the thickness of the resin is adjustable. Thus, the thickness of the substrate support members 47 is adjusted.

The fourth preferred embodiment of the present invention will now be described in reference to FIG. 6.

Now referring to FIG. 6, a diagram illustrates a partially enlarged cross-sectional end view of the motor compressor 10 according to the fourth preferred embodiment of the present invention. The sheet 46 of the first preferred embodiment is omitted in the fourth preferred embodiment. Additionally, in the motor drive circuit 41, the switching devices 44A are arranged at a distance from

the surface 43a of the substrate 43. Tabular device support members 55 made of resin are interposed between the surface 43a of the substrate 43 and the switching devices 44A in the motor drive circuit 41. The device support members 55 respectively support the switching devices 44A on the substrate 43. Accordingly, a load is generated on the switching devices 44A due to force pressing against the first housing element 21, and the load is appropriately received by the substrate 43 through the device support members 55. Therefore, even when the switching devices 44A are arranged at a distance from the substrate 43, stress due to the above load is prevented from intensively exerting at a soldering portion of the mounting support of each switching device 44A on the substrate 43. As a result, the soldering portion is prevented from being damaged.

Furthermore, in the fourth preferred embodiment, the force pressing the switching devices 44A against the first housing element 21 is adjusted by adjusting the thickness of the device support members 55, the thickness of which corresponds to the height or the lifting of the switching devices 44A from the substrate 43. Accordingly, the above adjustment substantially cancels absolute and relative inconsistent height of the switching devices 44A so that the switching devices 44A are prevented from being inconsistently pressed against the bottom surface 35a of the accommodating space 35. This leads to improvement in heat radiation performance of the switching devices 44A and stable arrangement of the motor drive circuit 41 in the accommodating space 35.

Additionally, the device support members 55 are used for adjusting pressing force of the switching devices 44A so that the structure of the motor compressor 10 becomes simple.

The present invention is not limited to the embodiments described above but may be modified into the following alternative embodiments.

In alternative embodiments to the above preferred embodiments, the sheet 45 is omitted. Namely, the heat radiating surfaces 44A-1 of the respective switching devices 44A are in directly contact with the bottom surface 35a of the accommodating space 35 in the first housing element 21.

In alternative embodiments to the above preferred embodiments, a bolt stopper is additionally used for fixing the motor drive circuit 41 in the accommodating space 35. In this state, the motor drive circuit 41 is bolted to the first housing element 21 or is bolted to the cover member 38.

In alternative embodiments to the above preferred embodiments, the motor compressor is a hybrid compressor that includes two drive sources for driving the compression mechanism 14. For example, the two drive sources are an electric motor and an engine for driving a vehicle.

In alternative embodiments to the above preferred embodiments, the compression mechanism 14 is not limited to a scroll type. For example, a piston type, a vane type and a helical type are applicable.

Therefore, the present examples and embodiments are to be considered as illustrative and not restrictive, and the invention is not to be limited to the details given herein but may be modified within the scope of the appended claims.